Time Critical Team Training in Virtual Worlds

by

Sainath Parab

A Thesis Presented in Partial Fulfillment
of the Requirements for the Degree
Master of Science

Approved November 2010 by the
Graduate Supervisory Committee:

Kanav Kahol, Co-Chair
Winslow Burleson, Co-Chair
Baoxin Li

ARIZONA STATE UNIVERSITY

January 2011

ABSTRACT

In the modern age, where teams consist of people from disparate locations, remote team training is highly desired. Moreover, team members' overlapping schedules force their mentors to focus on individual training instead of team training. Team training is an integral part of collaborative team work. With the advent of modern technologies such as Web 2.0, cloud computing, etc. it is possible to revolutionize the delivery of time-critical team training in varied domains of healthcare military and education.

Collaborative Virtual Environments (CVEs), also known as virtual worlds, and the existing worldwide footprint of high speed internet, would make remote team training ubiquitous. Such an integrated system would potentially help in assisting actual mentors to overcome the challenges in team training.

ACLS is a time-critical activity which requires a high performance team effort. This thesis proposes a system that leverages a virtual world (VW) and provides an integrated learning platform for Advanced Cardiac Life Support (ACLS) case scenarios. The system integrates feedback devices such as haptic device so that real time feedback can be provided. Participants can log in remotely and work in a team to diagnose the given scenario. They can be trained and tested for ACLS within the virtual world. This system is well equipped with persuasive elements which aid in learning.

The simulated training in this system was validated to teach novices the procedural aspect of ACLS. Sixteen participants were divided into four groups (two control groups and two experimental groups) of four participants. All four

groups went through didactic session where they learned about ACLS and its procedures. A quiz after the didactic session revealed that all four groups had equal knowledge about ACLS. The two experimental groups went through training and testing in the virtual world. Experimental group 2 which was aided by the persuasive elements performed better than the control group.

To validate the training capabilities of the virtual world system, final transfer test was conducted in real world setting at Banner Simulation Center on high fidelity mannequins. The test revealed that the experimental groups (average score 65/100) performed better than the control groups (average score 16/100). The experimental group 2 which was aided by the persuasive elements (average score 70/100) performed better than the experimental group 1 (average score 55/100). This shows that the persuasive technology can be useful for training purposes.

To my parents

ACKNOWLEDGMENTS

I would like to thank Dr. Kanav Kahol and Dr. Winslow Burleson for their guidance and encouragement. I would like to thank Dr. Kahol for giving me an opportunity to work in Human Machine Symbiosis Lab on this challenging problem. I would also like to extend my gratitude to him for his belief in me and for his constant support throughout this project.

I would also like to thank Dr. Baoxin Li for his invaluable time and effort to help me fulfill the degree requirements.

I am thankful to my colleagues Prabal, Kai and Miguel for helping me throughout this project. I would also like to thank my other colleagues Mithra, Aaron, Susannah, Kumar, Gazi, Akshay, Cecil, Camilla, Cord and Chris for their support.

I am grateful to all my friends at Arizona State University for making my stay very enjoyable. I would like to thank my roommate Chinmay for encouraging me throughout the span of my course.

I would like to thank my Academic advisor Martha Vander Berg for her help and assistance with administrative tasks.

Lastly, I would like to thank my parents without whom this would have remained, merely a dream. I would also like to thank Smriti for her support, encouragement and motivation.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. INTRODUCTION

Teamwork is considered to be one of the crucial aspects to attain success in several domains such as healthcare, military and aviation (Crew Resource Management). Effective and efficient team performance requires every team member to excel in their individual roles and co-ordinate their actions with other team members. Team performance also depends on the level of emphasis given to team training because emphasis on team training as opposed to individual training has shown significant performance improvement (Hamman 2004). One of the key aspects of teamwork is time criticality. Along with teamwork, it plays a crucial role in activities such as emergency medical procedures and tactical missions (civil or military). So it becomes necessary to introduce time criticality as a part of training exercises while delivering team training.

The objective of training is to impart knowledge to trainees. This knowledge can be theoretical, practical or both. Generally training is delivered using didactic sessions such as lectures or presentations. However, humans tend to learn more when the training is provided using multiple interactive means instead of monotonous didactic sessions. Several studies show that learning is faster and more effective when it is delivered using multisensory information (Seitz, Kim, and Shams 2006) (Shams and Seitz 2008). The word 'multisensory' signifies the involvement of multiple sensory modalities in humans. Such type of training is delivered using auditory, kinesthetic and visual sensory information. For example, mannequin based simulation training provided for medical procedures. It is important to provide time critical team training, augmented with multisensory information.

In order to work as a team, individual team members need to go through team training exercises. Conventional team training requires all the ream members and the trainer to be present at the same location. The team members go through several practice sessions and training exercises. However, it is not always possible to simulate real life situations for training because of predicaments such as unavailability of the required equipments and necessity of trainer and teammates to be present at the same time and location. Moreover, the mistakes committed during the training sessions can be expensive or hazardous. Virtual reality can provide alternate solutions to overcome these challenges.

Virtual reality is a term used for computer simulated environments where real world objects and places can be simulated. With rapid development of computer storage, memory, processors, and high speed network infrastructure, it is now possible to create virtual reality based simulations in a networked (distributed) virtual environment. These distributed virtual environments can revolutionize the delivery of time critical team training. In the modern era of technology, asserting that computers or internet have become ubiquitous would be an understatement. The past decade has shown us the growth of technologies such as web 2.0, cloud computing, service oriented architecture and social networks. Collaborative Virtual Environments (CVEs) also known as Virtual Worlds is one such emerging facet of technology, gaining attention of researchers, educators and students.

CVE or virtual world is a three dimensional virtual environment where virtual representation of real world objects such as buildings, trees, terrains and places are simulated. For example, Figure 1 shows a building surrounded by trees and terrain in the virtual environment. Virtual worlds present perceptual stimuli provided in the form of auditory and visual sensory information. They provide a social, interactive and shared space hosted in the internet. People can log in from disparate locations and can interact with other people as well as the environment. They are offered a variety of avatars. An avatar is a three dimensional graphical representation of human in the virtual world.

Figure 1. A building in virtual world

Virtual worlds have been used in several domains such as gaming (Brown and Marek 2004), online community building or socializing (Brown and Marek 2004), educational or working environments (Toups et al. 2009) (Callaghan et al. 2009). Figure 2 shows an example of a virtual classroom where an interactive learning session is in progress.

Virtual worlds are capable of conveying the social dynamics such as cooperation, appraisal and communication to the users in appropriate manner.

Moreover, in virtual worlds, users can assume different roles such as instructor, student, trainer and trainee.

Figure 2. People interacting in a virtual environment.

Current virtual worlds support various media sources such as text, audio and video. It is easy to provide auditory and visual sensory information to the user. This provides a limited amount of immersiveness. Currently, feedback devices such as haptic devices cannot be used to provide kinesthetic sensory input to the user in the virtual world. Haptic devices provide tactical feedback through user's sense of touch by applying force and vibration. Using haptic devices, it is possible to provide perception of three dimensional virtual objects. Figure 3 shows various available haptic devices. Integration of haptic devices with virtual worlds will enable us to provide this additional sensory feedback.

Figure 3. Haptic Devices

1.1 Motivation

A major issue in education has been motivating the user to learn. Many efforts of simulation training have had limited success in the past because of user motivational issues (Fogg 2002). Users need to be motivated to adapt to the new learning environment. Persuasion can facilitate to motivate users; persuasion is capable of achieving desired behavior modification in users (Fogg 2002). It consists of numerous persuasive components such as incentives (points, score) given to the user, notifications (alerts, warnings) given to the user and competition between the users. Competition is one of the most prevalent persuasive components seen in multiplayer games. Users tend to perform better when they are competitive (Rodrigo de and Nuria 2008). Fogg (2002) refers to such components and techniques that motivate users to change their attitude and/or behavior as 'Persuasive Technology'.

In the past, parents, teachers, friends and colleagues used to play the role of persuaders. Based on their request, opinion and suggestion one would change or at least try to change his/her behavior and/or attitude. However, modern interactive systems are capable of persuading human users better in specific contexts. For example, modern games persuade users using competition in gaming context.

With abundant features, virtual worlds are well suited for motivating users in order to adapt to the system. Fogg (2002) mentions that modern technology such as computers can be better at persuading users than humans because, they are more persistent; they provide greater anonymity; they can offer various modalities; computer programs can be rescaled according to user's needs and computers can be ubiquitous. Virtual worlds can provide all these features. They are more persistent; various input output methods can be integrated with virtual worlds, they can be scaled according to the requirement and they can be accessed from any part of the world. Hence, virtual worlds can serve as an integral part of persuasive technology.

However, virtual worlds have limitations that must be overcome in order to provide effective time critical team training. They are limited to provide auditory and visual feedback and support only conventional input/output devices such as keyboard, mouse and monitor. They do not provide support for additional sensors such as haptic devices and accelerometers and they also need to be programmed in order to support these devices. Rendering smooth haptic feedback over the internet poses further challenges such as requirement of high bandwidth network. Not all the virtual world vendors provide software development kits (SDKs). SDKs are required to program and customize virtual environments.

1.2 Objectives

The objective of team training is to impart knowledge to the subjects that are working together as part of training and improve their skills as a team in terms of effectiveness, efficiency and coordination.

Virtual worlds have potential to provide team training. In this study, we design and develop an interactive collaborative team training simulator that motivates users to perform as a team in time constrained environments.

The study focuses on following objectives:

- Evaluate the validity of virtual worlds on delivering team training for time critical activities.
- Evaluate the effectiveness of persuasive technology for learning of time critical multisensory skills.
- Monitor and record activities (and hence performance) of users while performing a collaborative task and come up with various metrics to judge the performance.

1.3 Document Outline

Rest of the document is organized as follows. Chapter 2 describes background and related work. Chapter 3 describes conceptual design. Chapter 4 gives details about methodology and describes the implementation. Chapter 5 describes the experimental results which includes experimental setup and assessment of results. Chapter 6 concludes this work.

2. BACKGROUND AND CASESTUDY

The thesis presented here deals with a particular type of time critical multisensory training in the clinical domain called Advanced Cardiac Life Support training. This section provides some background information on the procedure and its nuances. ACLS can serve as an appropriate case study to evaluate whether virtual worlds can provide effective time critical multisensory team training.

Advanced Cardiac Life Support (ACLS) refers to clinical interventions intended to treat life threatening medical emergencies such as cardiac arrests and respiratory failures. ACLS is a time critical team-based activity that requires cognitive and kinesthetic expertise. Mastering ACLS requires extensive medical knowledge, training and practice. Only qualified healthcare professionals such as physicians, nurses and paramedics can provide ACLS as it requires several skills such as understanding emergency pharmacology, managing patient's airway and interpreting electrocardiograms (Aehlert-Mosby 2006).

Life threatening situations such as cardiac arrests are announced as code blue emergency situation in hospitals. It is used to alert the staff about the situation so that they are aware and able to react to the situation as fast as possible. Code Blue indicates that there is a patient who is suffering from a severe life threatening situation and he/she requires immediate resuscitation (needs ACLS). Modern hospitals have a dedicated team of healthcare professionals who specialize in responding to these situations. The team needs to become aware of the situation quickly and act accordingly since the patient needs immediate attention. The delays in response may lead to serious consequences including mortality.

Complete knowledge about the procedure is one of the most important skills that an ACLS team member should possess. Each team member is evaluated against the knowledge of the procedure, decision making and leadership skills.

Every ACLS effort must have an assembled team and a designated leader who assumes the responsibility of overseeing the actions of the team. The team leader directs each team member and oversees the overall team progress.

2.1 Resuscitation basics

While the code is in progress, the team leader acts as the single point of authority. He/she needs to take initiative and assign proper roles to the team members while welcoming suggestions and ideas from them. The leader needs to guide the team through various resuscitation procedures.

During an ACLS effort, two most important priorities of the team are cardiopulmonary resuscitation and defibrillation (giving shock to the patient). There are two types of rhythms (EKGs) associated with ACLS namely, shockable and non-shockable. The patient having shockable rhythm should be defibrillated (shocked). Advanced airway, vascular access and medication are secondary actions. The next steps should be taken according to the rhythm present. For example, if there is no electrical activity and the patient is in cardiac arrest then the situation is identified as asystole. If the monitor shows normal sinus rhythm and there is no central pulse present then it is identified as Pulseless Electrical Activity (PEA). If the rhythms on the monitor are identified as either Ventricular

Tachycardia or Ventricular Fibrillation, urgent defibrillation is required. If there is any delay in getting defibrillator ready, CPR should be initiated right away. If the patient is in PEA or Asystole, defibrillation is not recommended. At any point in time, while ACLS is in progress, if patient's rhythm changes then the ACLS procedure should be changed according to the new rhythm.

When the patient is about to be defibrillated, everyone should be notified to be cleared off the patient. Negligence in these activities may result in severe consequences. Once the shock is delivered, the chest compressions and artificial respiration should be resumed. Pulse checks should take place periodically and emergency care should be continued according to the appropriate procedure.

2.2 Roles

ACLS is a team effort where each team member is required to assume different roles. Everyone is required to be thorough with his/her duties respective to the role. If the team members haven't assumed these roles then the team leader should quickly assign them the roles as they assemble. The required roles/duties are listed as below.

- Leadership
- Airway Management
- Cardiopulmonary Resuscitation
- Electrocardiogram monitoring and Defibrillation
- Emergency medication

The person who assumes leadership directs the entire team and ensures that each team member is performing assigned responsibilities properly and safely. He ensures proper interaction and communication between team members. Airway management is essentially managing artificial respiration for the patient. The person performing CPR should be replaced by other team member every two minutes. One of the team members is required to operate defibrillator. Defibrillator is a device that facilitates monitoring patient's EKG rhythm and allows defibrillating patient if required. One of the members is required to give medication. The knowledge of emergency medication is required in order to give proper medicines in a timely manner.

2.3 ACLS: Current training approach

Healthcare organizations provide regular ACLS training to facilitate emergency care providers to enhance their ACLS skills. A didactic session is conducted prior to the practical training. In a typical ACLS training session, first the team goes through an initial practice test for a particular EKG rhythm. The process is initiated by assigning roles, then dividing the tasks according to the roles, and following the tasks. The team's performance is monitored and evaluated by an evaluator throughout the period. After the session, the evaluator debriefs about the positive and negative feedback of their performance. Next the team goes through training for all the EKG rhythms. At the end of the training session, the team performs an evaluation test for the same rhythm as the initial practice test. Their performance is evaluated by the same evaluator to verify whether there is a noticeable improvement.

While this training is an effective methodology, it has some inherent limitations. The cost associated with overall setup such as necessary equipments is high, and the entire training session is time consuming. There is limited number of ACLS professionals available for training. Apart from these, ACLS training sessions are held once in every month. However, every single trainee is not required to attend the training session every month. This is an issue, considering the criticality of ACLS.

Virtual worlds can provide a cost-effective solution that can augment the efforts of ACLS training professionals by providing an automated system for training, testing and verifying retention of ACLS skills. Virtual worlds are capable of providing a centralized platform where participants can log in from remote locations. Because of its requirements, ACLS is an excellent candidate as a case study to verify whether virtual worlds are capable of providing time critical multisensory team training.

3. RELATED WORK

Our hypothesis is that team training can be effectively delivered using virtual world simulations augmented with persuasive components. As shown in the Figure 4, in this thesis, these three areas are combined to provide effective team training for time critical tasks. Previous work done in these areas is discussed below.

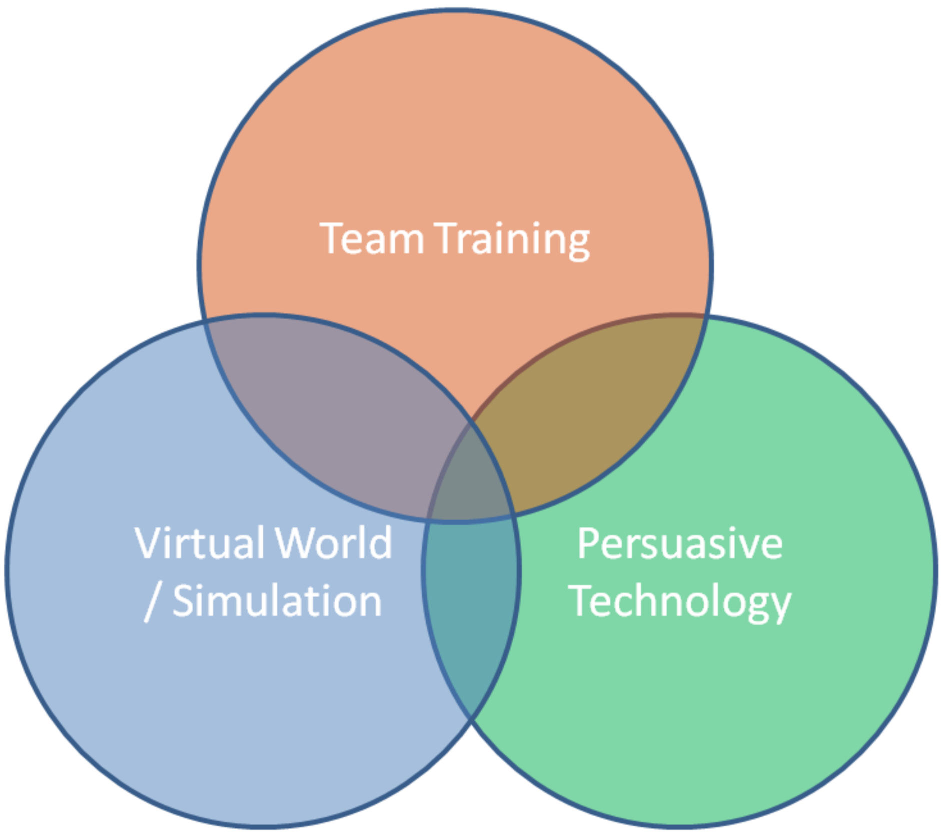

Figure 4. Venn Diagram of research areas involved in the dissertation

3.1 Team Training

Any coordinated effort, performed by a number of people in a group is termed as team work. Communication, coordination and cohesion are typical characteristics of a team. All the team members should possess these skills to efficiently carry out the assigned task.

Implicit coordination is one of the characteristics of high performance teams, where communication overhead is very less because the participants have access to the information without asking explicitly (Entin and Serfaty 1999). Communication overhead is typically the cost of communication/interaction measured in time and internet bandwidth (MacMillan, E., and Serfaty 2004). Another aspect that vitally affects an individual's ability to work in a team is shared mental models. As team members engage in a group activity, they tend to have similar thoughts/ideas in order to accomplish the task. This ultimately results in less communication across the team (Cannon-Bowers, Salas, and Converse 2001). These aspects are essential parts of team dynamics and should be considered in a design phase of any experimental groupware activity.

There have been some attempts at developing team training for Advanced Cardiac Life Support (ACLS). Simulation training is one of the best solutions available till date. According to Wayne et al, simulator training has shown significant performance improvement in a team of physicians while performing ACLS (Wayne et al. 2006).

Every single case of care delivery in hospitals involves a team of healthcare professionals. However, individual training is given more importance in clinical situations (Hamman, Beaubien, and Beaudin-Seiler 2009). There are various reasons behind this discrepancy. Some of the reasons include that it is often difficult to set up training sessions according to each individual's schedule;

team may consists of members from disparate locations and individual training is easier to conduct and requires less time. However, training a team together has been observed to be more effective way to improve the team performance. Interacting with team members during the training is a great way to reinforce the relevance of training. Team training also enables team members to learn about each others' strengths and weaknesses which is a very important aspect of team dynamics. Team training could prove to be more effective than individual training if these characteristics are taken into consideration while planning the training the sessions.

3.2 Virtual Worlds

Based on their purpose, Collaborative Virtual Environments (CVEs) or virtual worlds can be categorized into one of the following types: gaming, socializing or online community building, and educational or working environments (Tsiatsos, Andreas, and Andreas 2009). (Tsiatsos et al. 2009) outline the various factors that need to be present in a virtual world to be suitable for educational purpose. They compare various virtual worlds and come to the conclusion that selection of a particular virtual world depends on the purpose of the training system.

It is interesting to look at the current research on use of virtual worlds in healthcare and education. Wiecha et al explored the potential of a virtual world, Second Life (SL), as a teaching tool for continuing medical education (CME) (Wiecha et al. 2010). In their study, 10 participant physicians were made to select and adjust insulin level for patients with type-2 diabetes. Participants had to listen to an instructional 40-minute insulin therapy talk. Two mock patients (automated agents) were included in the study so that the participants could interact with the patients, and discuss within themselves. The study was designed such that the participants had to take a questionnaire before their training and after the training. The study revealed that the percent of participants providing a correct insulin initiation plan increased from 60% (6 of 10) pre to 90% (9 of 10) post (P= .2), and the percent of participants providing correct initiation of mealtime insulin increased from 40% (4 of 10) pre to 80% (8 of 10) post (P= .09). The study noted significant improvement in the participants and revealed that virtual worlds are very helpful for continuing medical education.

Callaghan et al (2009) used Second Life to create a virtual learning environment for engineering education. They demonstrate various interactive simulations that are part of engineering education (Callaghan et al. 2009). Apart from the simulations, a virtual lecture theater is also present in the virtual world which contains interactive slideshow viewer, media centre for streaming video content and message centers for feedback. It is not possible to program and customize the virtual environment according to your requirements as Second Life does not provide Software Development Kit (SDK). The authors used open source e-learning software SLOODLE that links Second Life with a course management tool known as MOODLE. After simulation training, the participants were asked to take a quiz; if they answer it incorrectly, they have to run the simulation again and answer the questions correctly. However, the study lacks the assessment and the evaluation of participants and they mention that these shortcomings will be their main focus in the future.

Boulos et al described the potential use of Second Life in medical and health education. The authors provide two scenarios, 'Virtual Neurological Education Centre' (VNEC 2006) and 'HealthInfo Island' (Info 2005). The former demonstrates a scenario where users are exposed to most common neurological disability symptoms. Apart from the symptoms, they are also provided with related information, events, and facilities in the Second Life. The latter involves providing training programs for virtual communities. It also intends to provide support to Second Life residents by giving them opportunities to participate in different medical groups dealing with stroke support and cerebral palsy.

The research study performed by Chodos et al. (2010) focuses on the development of a virtual environment to enhance communication skills for health science education. They talk about two case studies. The first one is the development of EMT/ER training simulation, which delivers an environment to train EMT/ER personnel on taking care of accident victim before taking him to a hospital. This case also focuses on exchange of patient information between EMT and ER personnel. The second case is designed to teach various competencies to students like rehabilitation medicine, nutrition, physical education etc. For the second case, the authors design a simulation in order to increase communication between the students to develop a home-care plan for elderly patient. Based on the case studies, they discuss the expectations of students towards virtual world based learning and the quality of learning.

There are several other projects that focus on virtual healthcare system. Second Health is one of such projects where users can learn about how to use medical devices in hospital settings (Health 2009). An interactive clinical scenario is provided for medical device training in simulated clinical environment. The participants are provided with both formative and summative feedback during the training session. However, the system does not provide clinical-skills training component in a collaborative environment where multiple users make a team and perform a collaborative task. Similarly, the Ann Myers Medical Centre (Center 2009) and the nursing training program from Duke University (Johnson C 2009) provide meeting places for medical educators and students, where instructors can present lectures and present educational materials, and students can interact with each other.

3.3 Persuasive technology

Persuasion is one of the most important factors that can affect the performance of trainees/students in medical training/education. Use of meaningful persuasive components such as rewards, realism and social presence enhances the learning where as bad design of persuasive components hinders it. This section discusses some of the research work that has been done to motivate users to perform activities within a given system.

Conradi et al. (2009) propose an idea of collaborative learning through problem-based learning (PBL) in Second Life, which they call PREVIEW. Five virtual patient scenarios were prepared for learners, which were later delivered to the learners through Second Life platform. The main objective of the study was to find whether computerized simulation based PBL can be more effective than classroom based PBL. To engage students effectively in training, the environment provided greater realism, active decision making, and suitable collaborative platform where the participants can interact with each other. The study shows that realism, and suitable interaction environment provided by Second Life engages students effectively in learning.

Burleson et al (2004) talk about potential of affective agents (affective learning companions) in influencing perseverance in the face of failure. They show that subjects can be motivated to learn through failures using affective agents. In this study, they propose a system where the subjects have to solve the Towers of Hanoi puzzle. The affective agents offer help if the user is facing failure or the user is stuck at some point otherwise they allow the user to explore the puzzle by themselves. They state that such motivation positively influences users without hampering their originality (Burleson and Picard 2004).

Consolvo et al (2006) look at the design requirements for technology to encourage physical activity. For this study, they come up with a mobile phone application to encourage users to perform physical activity. The application has three different versions: baseline, personal, and sharing. Sharing version was the most advanced where users not only can see their activity, but also can share their performance to others and view others performance. Based on their study, the authors described various factors that motivate users to perform physical activity. Giving proper credit on completion of each task, and providing personal awareness on users' past performance, and current performance are the basic elements of the system that persuaded users. Another important factor is social interaction. According to the authors, social influence creates social pressure, which motivates users to be the best in the society. This kind of systems can prove to be very effective for preventive healthcare, where certain measures are taken to minimize risk factors for diseases. TripleBeat (Rodrigo de and Nuria 2008) is also a similar kind of mobile phone based system that motivate runners to achieve predefined exercise goals using musical feedback as well as competition based persuasion, and real-time personal awareness. The experiment results conclude that the system is ‘significantly more effective’ in helping runners to achieve the goals.

Firpo et al (2009) explain the capabilities of blogs and podcasts as tools to provide more sense of community in a group. The objective of their study is to change attitude and behavior of a community at School of Information Systems and Technologies (SISAT) in order to foster a sense of community amongst its members. Based on the functional triad explained in (Fogg 2002), the authors conclude that social presence and credibility as the key factors to persuade the members in the community.

Several virtual reality based games have already evolved to motivate users to maintain good health. The following simulation based applications have proved the fact that simulated environments are very effective to change one’s attitude and behavior. The Tetrix VR Bike (Fogg 2002) is an environmental simulation that motivates users to work out on this device by exploring the virtual environment. The faster users pedal, faster will be the exploration. Another simulated environment is Bronkie the Bronchiasaurus (Lieberman 1995), which is designed to help kids with asthma to manage their condition. The study showed that the asthmatic kids who played the game for at least 30 minutes report increased self-efficacy to take care of their chronic condition. Similarly, HIV Roulette (Services 2006) is another simulation to provide immediate insights into sexual behavior. Users can view and select hypothetical character along with gender and behavior. Based on the selection criteria, the system reports whether the specified behavior is likely to cause HIV or any other sexually transmitted diseases.

3.4 Summary of limitations of previous work

Even though team training has evidently shown significant performance improvements in participants; individual training is given more preference. The reasons being, difficulties in setting up training sessions according to each individual's schedule and issues such as modern teams consist of members from disparate locations. Moreover, inaccurate user validation schemes and inadequate feedback provided by the system limit the user's ability to learn.

An effective system is required that can overcome these challenges and facilitate the delivery of team training. Virtual worlds are capable of providing such platform; however, some of the attempts of using virtual worlds have had limited success in the past because of usability issues and motivational issues. Users could not adapt to the system easily. User motivation plays a key role in the overall success of the system. Effective integration of persuasive components can facilitate learning and adapting to the system. Previously implemented systems lack the integration of additional sensors such as haptic devices and accelerometers to provide multisensory team training. Such a virtual environment, equipped with persuasive components and multisensory devices would prove to be effective for time critical team training.

4. CONCEPT DESIGN

4.1 Conceptual Design

In order to implement the platform for providing ACLS training in the virtual world, we laid out its concept design. One of the objectives of this system is to allow users to access the system from geographically disparate locations. Figure 5 shows the concept design of the system. The inner box depicts the ACLS training room inside the virtual world where all the required equipments, medicines, bed, and patient is simulated. The outer box depicts the real world where users can be logged in from disparate locations. The figure lists different roles that ACLS team members have to assume. The green circles in the figure depict users carrying out different roles. For example, user 1 is taking care of patient's breathing and user 2 is responsible for medication. Users can choose from variety of avatars of nurses and doctors. They are supposed to assume these roles as they assemble in the ACLS training room. User 3 is responsible for doing CPR. This user is connected with haptic device. He/she performs the CPR on the haptic device which gives haptic feedback. The system monitors the rate of compressions per minute, depth and recoil of the compressions. The haptic device is integrated with virtual world. User 4 is responsible for operation of the defibrillator and user 5 is the leader who coordinates the entire activity.

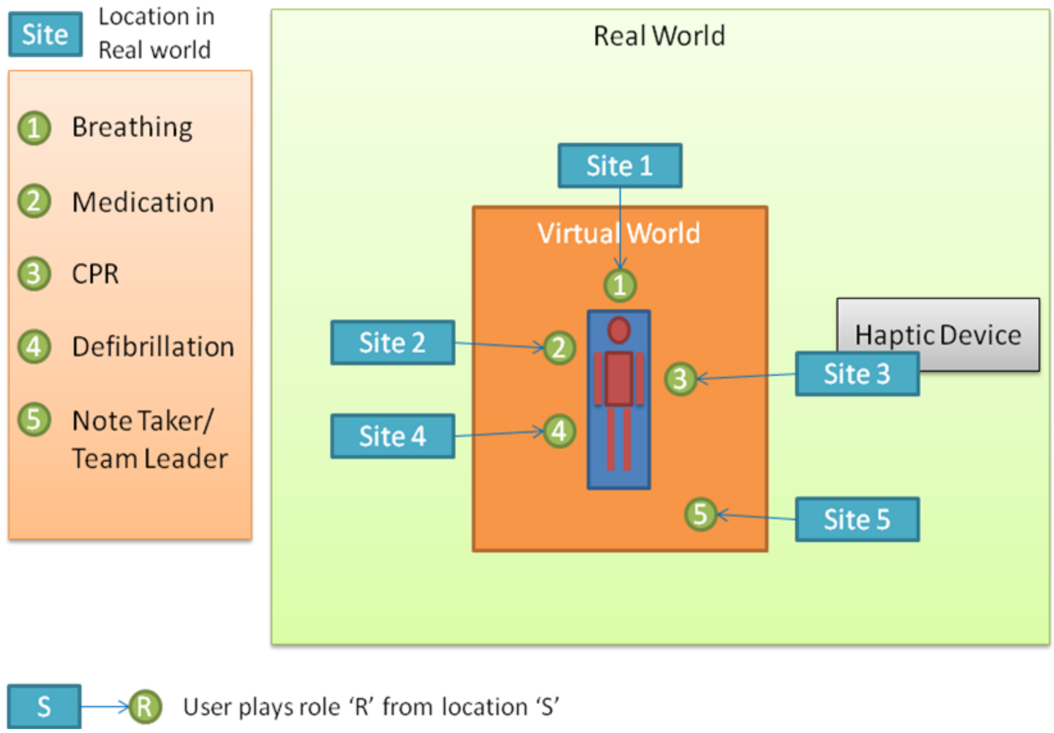

Figure 5. Concept Design

4.2 System Design

Figure 6 shows the system design that integrates different components of the system. It presents the information flow from one module to another. The users are logged in from remote locations. This figure is shown from the CPR user's perspective. He is the user at the local site in the system. He performs CPR on the haptic device which is connected to his computer. The haptic feedback is kept local. The haptic module is explained in detail in the next section.

When the participant starts performing CPR, it triggers the CPR animation sequence in the AW, which is visible to all the participants who are logged in to the system at that moment. Apart from animation sequences, the system also provides visual cues on what actions the participant(s) have to do next, such as giving medicine and putting oxygen bag. The team has to perform different actions in the exercise. All these actions are recorded in a centralized database. Other visual feedback components such as scores and summarized evaluation are also present in the system. Audio components are also made available in order to provide realism to the virtual environment. For example, ambient noises are present in the virtual world.

The users can make voice calls to each other using Skype. The integration of Skype with the system has two major benefits. Firstly, it facilitates realistic communication in the team during the exercise. Secondly, the conversation between the team members can be recorded for evaluation, since it is one of the key aspects that affect the team performance.

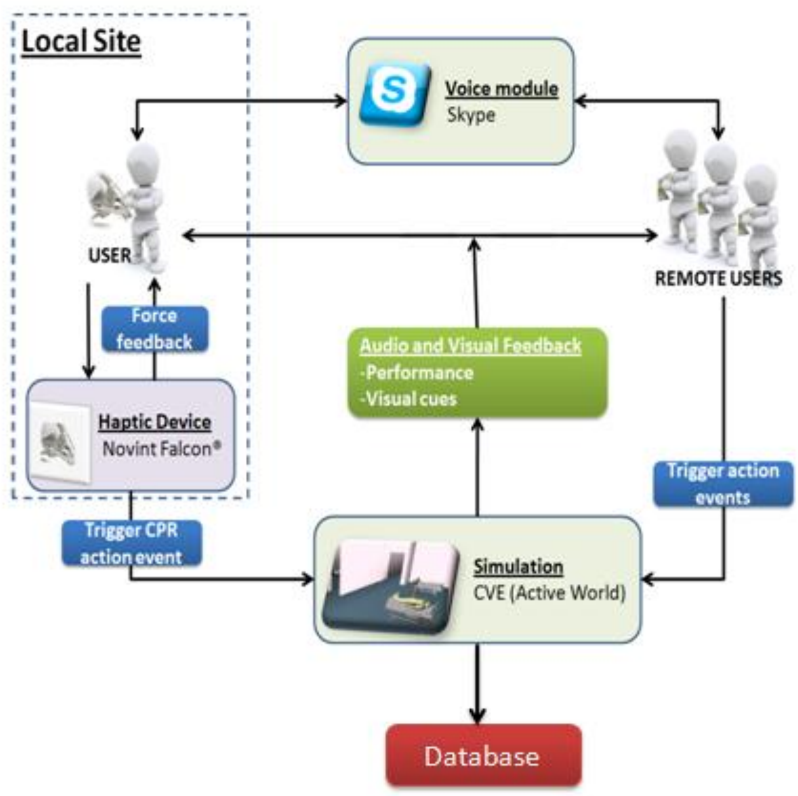

Figure 6. System Design

4.3 Description of ACLS procedure as performed in the virtual world

This section describes the ACLS training in the virtual world. There can be five different causes of cardiac arrest namely,

- Vantricular Fibrillation
- Ventricular Tachycardia
- Sinus Bradycardia
- Pulseless Electrical Activity (PEA)
- Asystole

These causes are recognized by identifying the patient's rhythm (EKG). Whenever the patient is having a cardiac arrest, the ACLS team has to diagnose the cause (one of these) and proceed with the treatment according to the respective procedure. These cause / their rhythms are classified into two categories namely,

- Shockable
- Non-shockable

For our implementation of training exercises, we chose the most common rhythms from each of these categories.

- Ventricular Fibrillation (Shockable)
- Pulseless Electrical Activity (PEA)

These rhythms are two of the most prevalent causes of cardiac arrest. Moreover, implementing one cause from each category allows participants to practice procedures from both the categories.

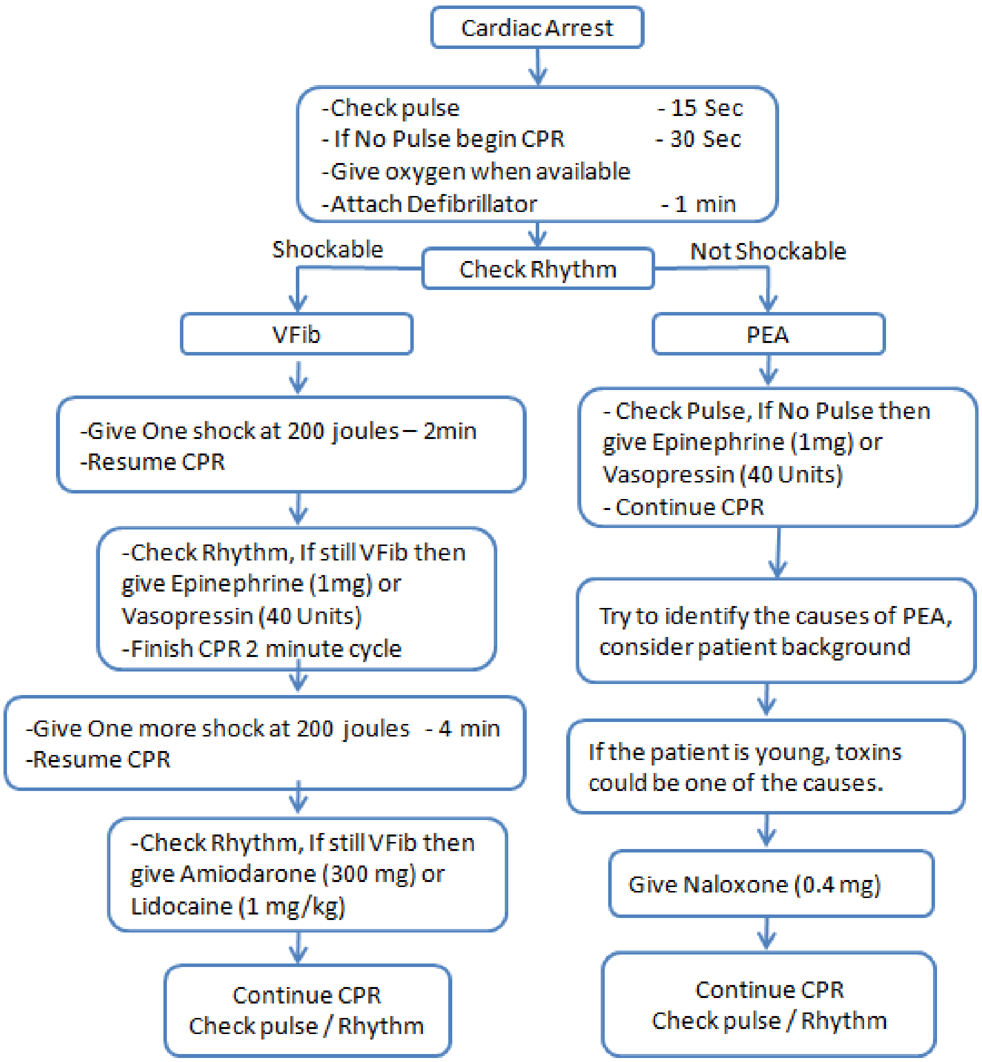

Figure 7. Procedure for treating VFib/PEA

Figure 7 shows the steps to be followed in order to treat either Ventricular Fibrillation or PEA. It lists out every step along with respective time limit for that particular step.

5. METHODOLOGY

5.1 System Modules

5.1.1 The Virtual World:

The virtual world module controls all the visual aspects of the simulator. We chose Active Worlds (Activewordls-Inc. 1995) as our virtual world platform to design and implement our virtual hospitals. Active Worlds provide Software Development Kit (SDK). that enabled us to program our own patient treatment scenarios.

We used original floor plans of simulation center from Banner hospitals. This allowed for better immersion of users in the virtual world and more “buy in”. Figure 8 shows Banner Simulation Center created in the virtual environment based on its original floor plans.

Figure 8. Simulated Hospital in our Virtual Environment

Users can log in to the developed virtual environment in Active Worlds’ browser using their credentials. After logging into the system, users can navigate in the virtual environment using their own avatars. Thirty participants can be logged in simultaneously in our system. The users can interact with each other through voice chat and can also see each other's actions within the virtual environment. Visual instructions are provided to users in the Virtual Environment. Apart from the instructions, users are provided feedback on their respective performances. The main components of our virtual environment are:

- Avatars
- Objects
- Animation Sequences

- Avatars:

Active worlds provide variety of avatars. They can navigate in variety of ways such as walk, run and fly in the virtual world. We developed our own avatars of physicians and nurses. They are developed using programs such as Maya and 3D Studio Max. Along with walking, running and flying they can perform gestures such as chest compressions and checking the pulse of the patient.

- Objects:

The virtual world is filled with objects. In our virtual world, hospitals, patients, chairs, tables, visual cues, instructions and buttons all are objects. All these objects are developed using programs such as Maya and 3D Studio max. They are converted into Renderware® object format which is the native format of Active Worlds. Figure 9 shows some objects that we created in the virtual world. Different kind of animation sequences can be applied to the objects. These animations can be showing/hiding objects and moving objects.

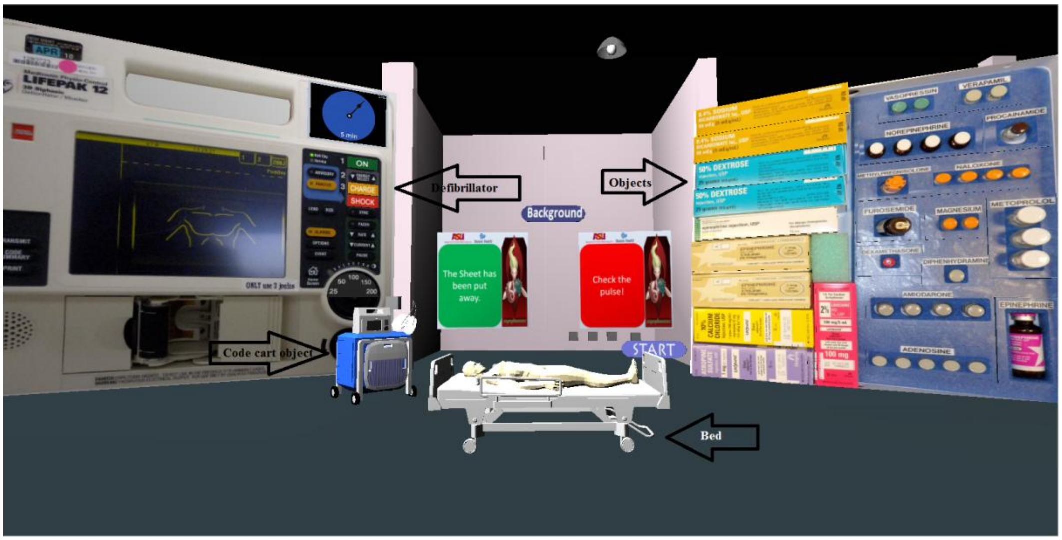

Figure 9. Some objects in the virtual world

- Animations:

Animations are parts of action sequences. In order to get an avatar to do certain movements, it is required to design animations and trigger the animation either automatically or through user inputs. In our virtual worlds, avatars are simulated to perform different animations such as chest compressions and checking pulse. We developed these custom animations using Lifeforms Studio. These animations are rendered as .seq (sequence) files. Active worlds associates these files with their respective avatars and creates a runtime animation in the virtual world.

Figure 10. Avatar of a physician performing CPR in the virtual world.

5.1.2 Haptic module

Haptic module allows the integration of haptic device and the virtual world. This integration plays a key role in evaluating CPR skills. The haptic module was developed earlier as a part of another innovative research project in our lab (Khanal P and Kahol K 2010).

This module mainly consists of two parts,

- Interaction with the haptic device
- Sending responses from the device to Active Worlds

The haptic device is integrated with Active Worlds to simulate an avatar performing CPR action. We used Novint Falcon® in our study because it is cost effective and it is easier to setup during experimental sessions. As shown in the Figure 11 when a participant simulates performing CPR action on the haptic device, the sensor thread on the local machine triggers an event of “CPR gesture” in Active Worlds server which in turn simulates an animation of avatar performing CPR action. This action is broadcasted to every user who is present in the same virtual room. Figure 12 shows a participant performing CPR on a haptic device.

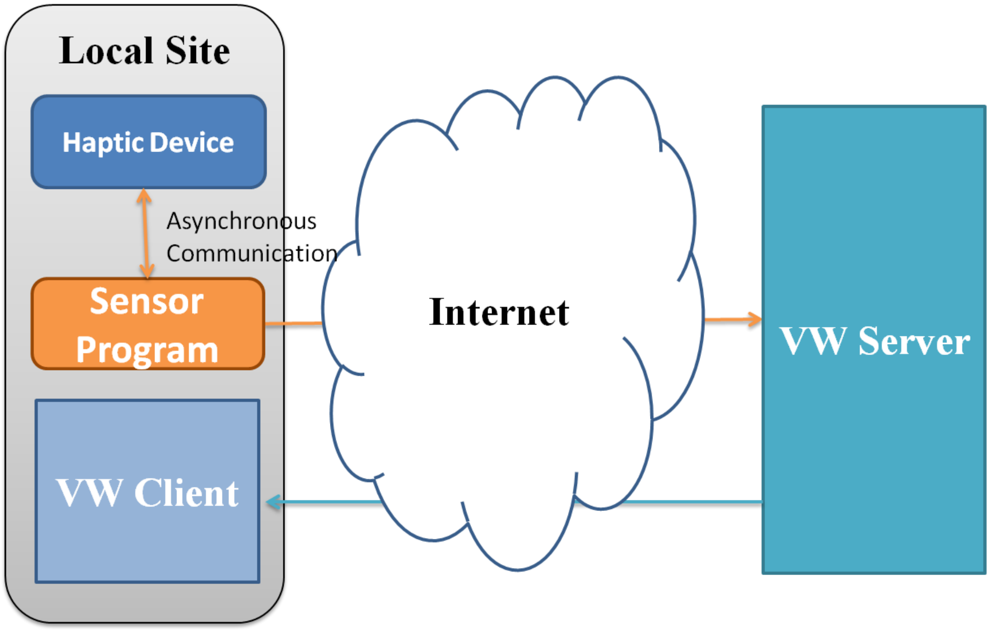

Figure 11. Design of haptic module

The main idea of using the haptic device is to give the perception of performing CPR in real world. Spring force is applied when the handle of the haptic device is pushed towards Y-axis. As the force resolution of Novint Falcon haptic device is not very good, we cannot render high force feedback. This would affect the performance while performing CPR as the surface would feel soft. To simulate harder surface, we placed a real spring just below the handle of the device so as to render harder force when the handle of the haptic device is pushed in. As we are concerned only with the calculation of the distance of the haptic joystick from the original position to the end position, this is a simple yet an effective way to increase the force feedback maintaining consistency of the haptic loop.

Figure 12. A participant performing CPR on a haptic device.

5.1.3 Voice module

The voice module provides more realistic team-work and team-coordination while performing a virtual procedure since it offers an easy way to communicate with the team members. We had a requirement of recording these conversations for further analysis. Based on the features and cost-effectiveness, Skype best fitted our requirements. Hence, we chose Skype over other software programs that provide computer-to-computer conference calls.

5.2 Persuasive Technology

Persuasion is intended to motivate the users. Persuasive elements facilitate the users in order to adapt to new system (Fogg 2002). Realistic objects, environment and presence of other participants motivate users to perform tasks in the virtual environment. Introducing real background sounds and noises adds to the realism offered by the environment. Use of affective agents for motivating participants has been noted previously (Burleson and Picard 2004). Figure 13 shows persuasive character (affective agents) in different moods. With different moods, the characters become more expressive. Depending on the team performance these characters appear at different times.

Figure 13. Persuasive character (affective agent) in different moods

Figures 14 and 15 show a virtual character giving instructions. Presence of other participants also affects the individual performance. Awareness of being a team member motivates every individual. Voice module facilitates communication across the team and enhances coordination among team members.

Figure 14. Virtual persuasive character giving instructions

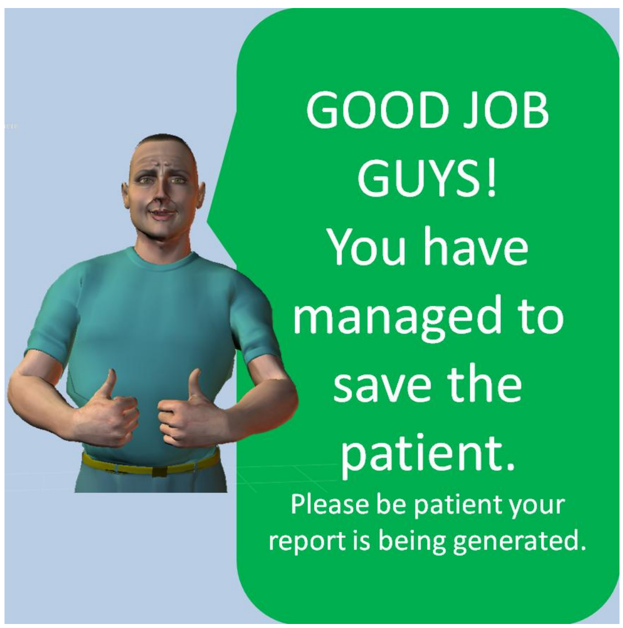

Figure 15. Virtual persuasive character shown after the patient is saved

5.3 Persuasive Techniques

The different types of persuasive techniques (Fogg 2002) used in this system are explained below:

- Tunneling
- Tailoring
- Self Monitoring

5.3.1 Tunneling

Tunneling is a process in which users are guided through the entire procedure. Users are prompted to perform first step and once they perform that step, the prompts with the subsequent steps until the goal is obtained. When the participants reach the virtual ACLS training room and start the procedure in the training mode, they are provided with the instruction to perform the first step. Figure 16 shows screenshot of the system at the start of the exercise. The first instruction is shown, “Click on the sheet to put it away” and an arrow is pointing towards the sheet. Figure 17 shows the next step to be followed (check the pulse in this case). Likewise, the system will guide the participants until they reach their objective.

Figure 16. Instructions and arrows are displayed in the virtual world

Figure 17. Next instruction is shown after the current instruction is followed

5.3.2 Tailoring

Tailoring is essentially abstracting the user from excessive information so that the user is not overwhelmed. Tailoring helps in two ways: first, they reduce the information based on a given context so that the information wouldn't be overwhelming to the users; second, the users need not memorize all the steps, they can easily recall what they know, if they are shown the options. In our system, there are various checkpoints where users have to decide which choice would be the best one to achieve their goal. At those checkpoints, we provide various options to them. They will make a choice and follow the procedure based on that choice.

Figure 18. Tailoring: Abstracting information from the user

5.3.3 Self-monitoring

Another important criterion for persuasive technology is to allow users to monitor themselves. It requires formative feedback for user on the performance during a procedure. In this system, we provide scores for each and every action that the users perform. If they do not perform the tasks or actions in a correct way, or within the pre-specified timeframe, then they are not awarded any points on those actions. This will enable users to monitor their collaborative work at any instant during the procedure. They are provided with status messages after every action they perform. This is another form of formative feedback provided by the system. As the team of the participants goes through the entire procedure, their each and every activity is recorded in the database. Based on this data, an automated report is created at the end of their performance and the participants are provided with a summative feedback. Figure 19 shows the evaluation report which lists out each and every action that was performed during the exercise (summative feedback). This report contains details about the team score, individual score and all the activities that were performed during the exercise. The report contains a table which lists all the activities, users who performed those activities and the times that of those activities.

Mock Code Evaluation Sheet

Team Code: 181

Team Score: 500

Click here for individual scores

test

Date of Session:	10/28/10
Time of start:	
Total Time Taken:	
Time of pulseless Recognition:	10
Time CPR/BLS initiated:	29
Time on Monitor:	53
Initial Rhythm:	VFib
Recognized Correctly:	VFib

Time of initial Defibrillation:	104	Time of 1st ACLS drug:	125	Drug:	Vasopressin
Time of 2nd Defibrillation:	238	Time of 2nd ACLS drug:	252	Drug:	Amiodarone
Time of 3rd Defibrillation:	-	Time of 3rd ACLS drug:	-	Drug:	-

Communication

Medication and Doses echoed back (Yes/No): Yes

Did you hear I NEED Yes I'M GETTING Yes I'M GIVING Yes

Summary Sheet

Serial No	Action/Gesture	Time	User	Score
0	Put the sheet away	3	SymCLE5	-
1	Checked pulse	10	SymCLE5	100
2	Take the pillow away	18	SymCLE5	-
3	Board placed under the patient	24	SymCLE5	-
4	CPR started	29	adminCLE	100
5	Oxygen on	46	SymCLE5	-
6	Defibrillator on	53	SymCLE7	50
7	Hands-free patches placed on the patient	70	SymCLE7	-
8	Rhythm recognized as VFib	77	SymCLE7	50
9	Joules level set	82	SymCLE7	-
10	Defibrillator charged	89	SymCLE7	-
11	Oxygen off	98	SymCLE5	-
12	Shock Delivered	104	SymCLE7	100
13	Checked pulse	108	SymCLE5	-
14	Vasopressin given (40 units)	125	SymCLE6	50
15	Checked pulse	210	SymCLE5	-
16	Joules level set	220	SymCLE7	-
17	Defibrillator charged	227	SymCLE7	-
18	Oxygen off	233	SymCLE5	-
19	Shock Delivered	238	SymCLE7	0
20	Checked pulse	242	SymCLE5	-
21	Amiodarone given (300 mg)	252	SymCLE6	50

Figure 19. Performance evaluation sheet (summative feedback)

5.4 Performance Evaluation

Evaluating performances was one of major challenges. Since the participants were supposed to carry out different actions in a timely manner, we defined three time-wise categories for every action. For example, the patient's pulse is supposed to be checked within first 15 seconds. Sooner the pulse is checked the better. So we divided this timeframe of 15 seconds in three categories as follows, if the pulse is checked under 5 seconds then 10 points are given, if the pulse is checked under 10 seconds but after 5 seconds then 8 points are given, similarly if the pulse is checked under 15 seconds but after 10 seconds then 5 points are given. Table 1 shows different actions and respective scores given per time-wise category.

Action List	Score
Check pulse	**10** (if Cp<=5sec); **8** (if Cp<=10sec); **5** (if Cp<=15sec)
CPR start time	**10** (if Cc<=10sec); **8** (if Cp<=20sec); **5** (if Cc<=30sec)
Defibrillator on	**10** (if Cd<=20sec); **8** (if Cd<=40sec); **5** (if Cd<=65sec)
Rhythm identified	**10** (if Cr<=25sec); **8** (if Cr<=50sec); **5** (if Cr<=75sec)
Shock delivered	**10** (if Cs1<=40sec); **8** (if Cs1<=80sec); **5** (if Cs1<=120sec)
Medication 1 given	**10** (if Cm1<=50sec); **8** (if Cm1<=100sec); **5** (if Cm1<=150sec)
Shock delivered	**10** (if (Cs2-Cs1)>=105 AND if (Cs2-Cs1)<=130), **0** else
Medication 2 given	**10** (if (Cm2-Cs2)<=10sec); **8** (if (Cm2-Cs2)<=20sec); **5** (if (Cm2-Cs2)<=30sec)

Table 1. Actions and respective scores given per time-wise category

According to this table we calculate scores for every action and then using following formula we calculate the final score for a team for the respective trial.

$$\text{Final Score} = 100 \text{ X } \frac{\text{Sum(score for each action)}}{\text{Sum (maximum score for each action)}}$$

This formula was used to calculate final scores of all the training and test trials in the virtual world as well as the simulation center. This metric was verified by professional ACLS trainer at Banner hospital.

6. EXPERIMENTAL RESULTS

6.1.Experimental Setup

In order to validate the system, a group of 16 participants (11 males and 5 females) was chosen. Their ages ranged from 21 years to 38 years. All of them were college students (undergraduate/graduate). None of them had prior ACLS knowledge.

These 16 participants were divided in four groups of four participants each.

- Control Group 1
- Control Group 2
- Experimental Group 1
- Experimental Group 2

Two control groups and two experimental groups were chosen to have comparison and validate virtual world as a training tool. Having multiple groups in the same category for data collection eliminates the possibility of bias in the data.

The experiment was arranged in three phases. The first phase consisted of a didactic session. The second phase was executed only for the experimental groups and consisted of training and testing ACLS in the virtual world. The third phase was mannequin based testing in a simulation center at Banner to measure the transfer in the participants.

In phase 1, all four groups attended a didactic session, where they were introduced to ACLS in a classroom setting. They were introduced to the devices that are used for ACLS. They were introduced to all the fatal rhythms (EKGs) and the respective procedures that treat those rhythms. They were asked to take a quiz after the didactic session. This quiz allowed measuring the effectiveness of didactic training and acquisition of theoretical knowledge about the ACLS protocol.

In phase 2, the two control groups did not receive any training in the virtual environment. The Experimental group 1 went through training in virtual world. This training did not involve any persuasive elements such as back ground sounds, persuasive characters, points showing scores etc. nor were they prompted to do any required actions in timely manner. As they were trained only on the procedure with no persuasion, we will refer to this group as the procedural group.

The Experimental group 2 also went through training in virtual world. This group was aided with different persuasive elements such as notifications, affective agents, background sounds, points and timeline. We will refer to this group as the persuasive group.

In phase 3, all the three groups were tested in Banner simulation center in a real world setting to measure the transfer of ACLS skills in the participants. Each group went through 2 tests on high fidelity mannequins. Figures 20 shows the groups performing in the simulation center. If the two experimental groups show significant amount of transfer then we can assert that virtual worlds are capable of delivering team training.

Figure 20. Transfer test in the Simulation Center

6.2 Results of Experimental Evaluation

All four groups had to take a questionnaire at the end of the didactic session. This was targeted to measure how much did they learn in the session. The questionnaire consisted of 10 multiple choice questions related to the information presented in the session. They were not asked to make any logical inferences; all the questions were straight forward. Figure 21 shows the results of the questionnaire. The means are not significantly different from each other and their standard deviations are also similar. This shows that all the groups had equal knowledge about ACLS after the didactic session.

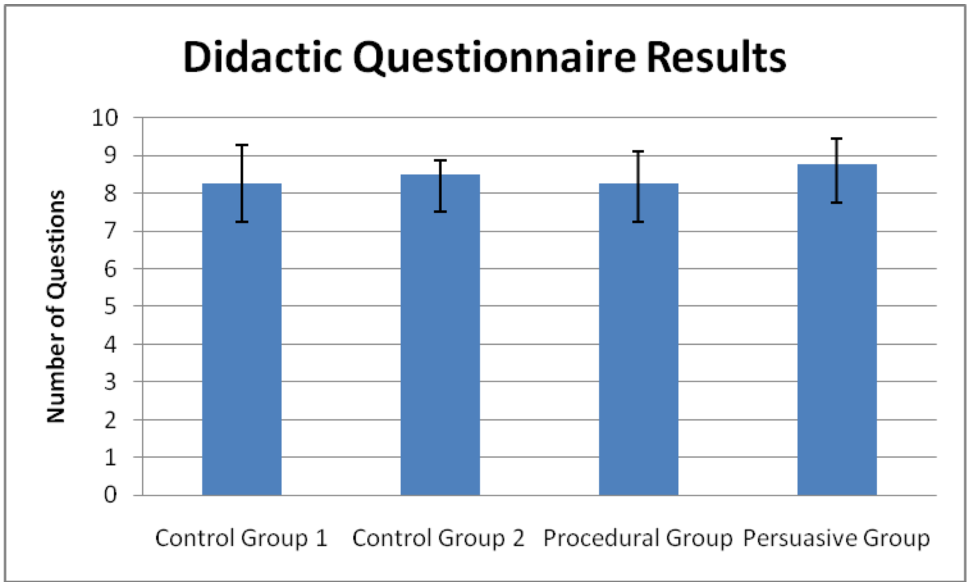

Figure 21. Didactic questionnaire results

In phase II, all the groups were trained for two ACLS procedures in the virtual world namely,

- Ventricular Fibrillation (VFib)
- Pulseless Electrical Activity (PEA)

In phase II, each of the two experimental groups went through two training trials of each of these procedures in our virtual world and was tested for the same procedures in the virtual world. Their performances were evaluated by our virtual world.

Following are the learning curves of two actions that were recorded while training and testing in the virtual world. Figure 22 shows the time that procedural group and persuasive group took to recognize the current rhythm of the patient. Figure 23 shows the time that procedural group and persuasive group delivered shock to the patient. We can see the time taken for these actions decreases progressively. During the training sessions, persuasive group was prompted by a persuasive character (affective agent). For example, if the group has not started CPR, then the character would appear and prompt them to start the CPR.

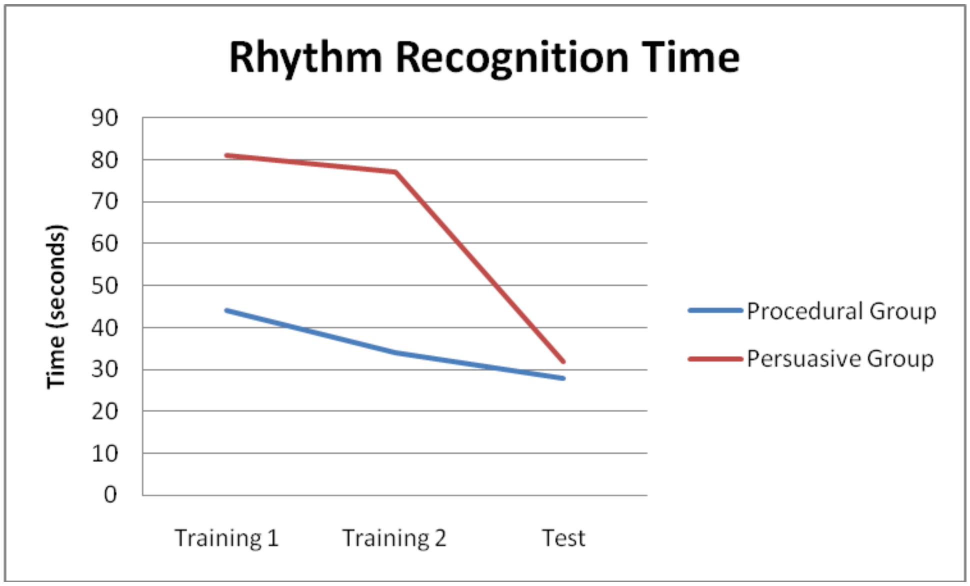

Figure 22. Time taken to recognize the rhythm in progressive trials (VW)

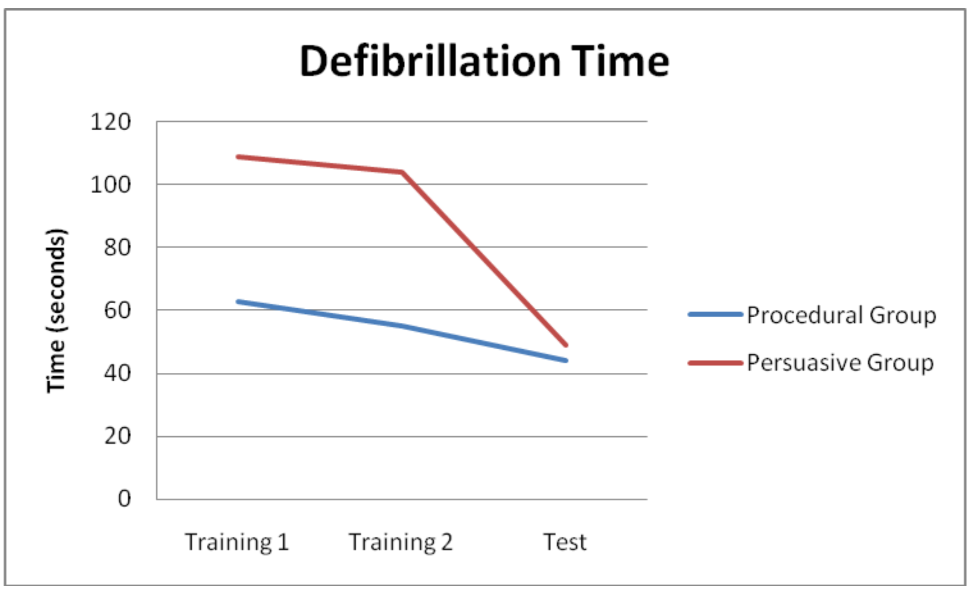

Figure 23. Times taken to deliver shock in progressive trials (VW)

Following charts show the performance of the procedural group and persuasive group in the virtual world training and testing.

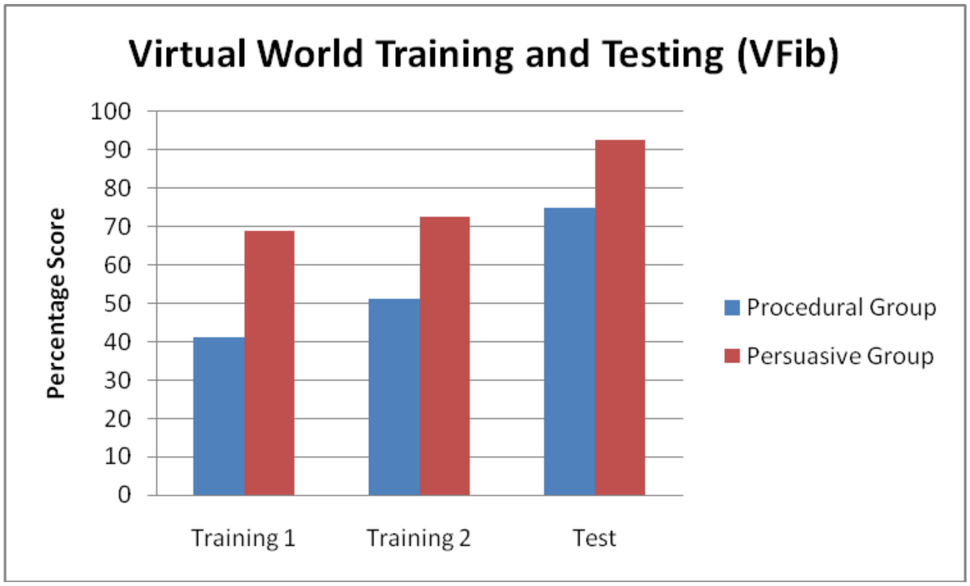

Figure 24. Percentage score of Virtual World Training and Testing (Vfib)

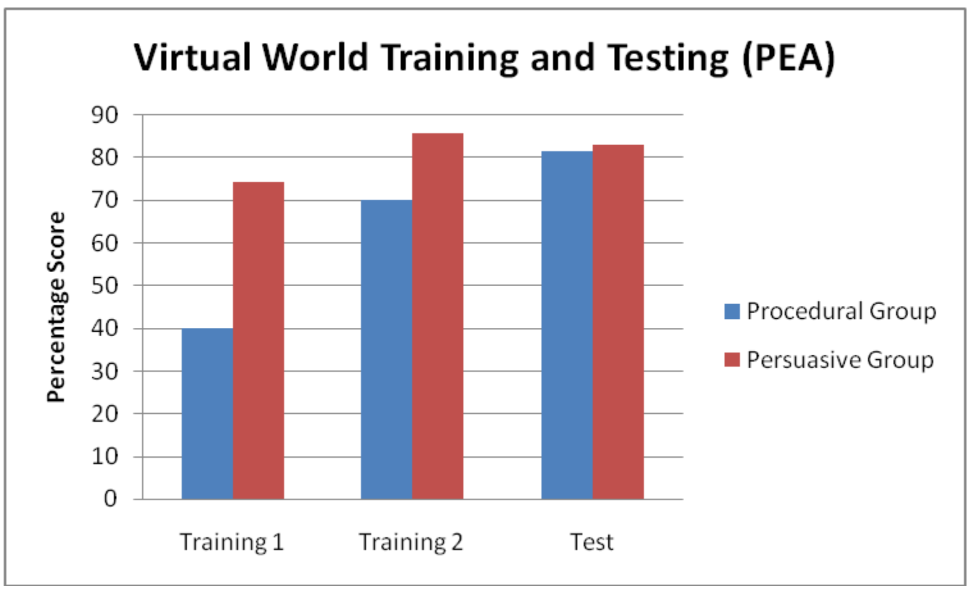

Figure 25. Percentage score of Virtual World Training and Testing (PEA)

The first and second bars in the figures 24 and 25 depict the performance during the training sessions. And the third bar depicts the testing session. It indicates that there is a considerable difference between procedural group and persuasive group. Both figures show that, in training trials the persuasive group started off very well as opposed to the procedural group. It also indicates that the learning curve of the procedural group is steeper than that of the persuasive group. We hypothesize that the persuasive elements actually help in the initial phases and aid the participants in adapting to the system. In case of VFib, the difference between the procedural group and the persuasive group is evident in training as well as testing trials. However, in case of PEA, we do not see much difference between the procedural group and the persuasive group. PEA is inherently different than VFib. It does not involve certain aspects such as defibrillation and consists of fewer steps as compared to VFib. This can also be a result of the order of trials in which the teams were trained. We suppose that these might be the reasons behind the above result.

In summary, the virtual world training and testing trials depict that effective learning is possible in virtual world.

In Phase III, all the four groups were tested in real world setting to measure the transfer efficacy. We tested the control groups to study the transfer of didactic training which is the conventional method and the experimental groups to identify the evaluation of the virtual world component as an add-on. They were tested for both the procedures (VFib and PEA) on high fidelity mannequin based tests and these test trials were randomized. The teams' performances were evaluated by ACLS professionals at Banner simulation center.

Figure 26 and 27 show the average percentage scores as per the scheme defined in Table 1. They indicate that Experimental group performed considerably better than the control group in both the procedures. These results suggest that Virtual world training is instrumental in the noted improvement.

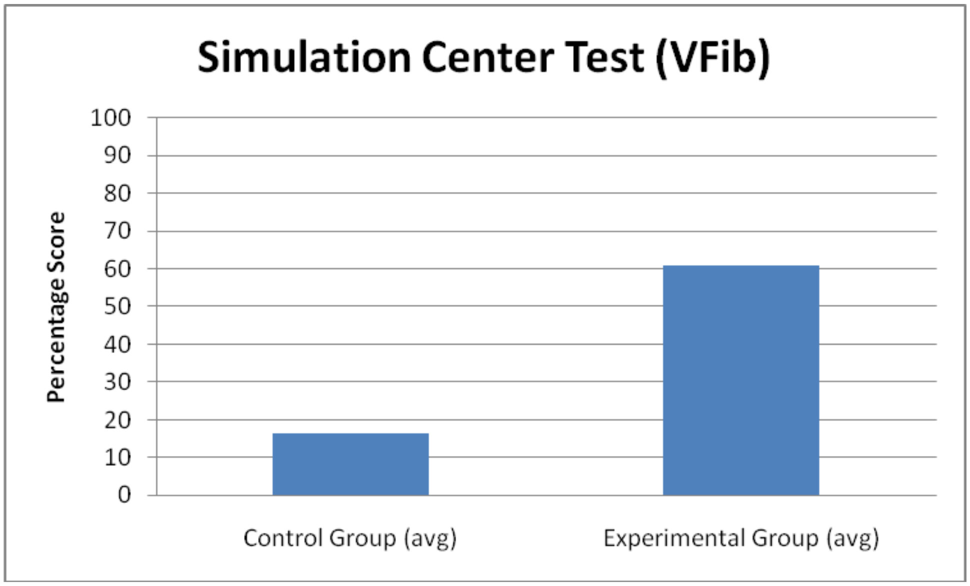

Figure 26 . Comparison between control and experimental groups

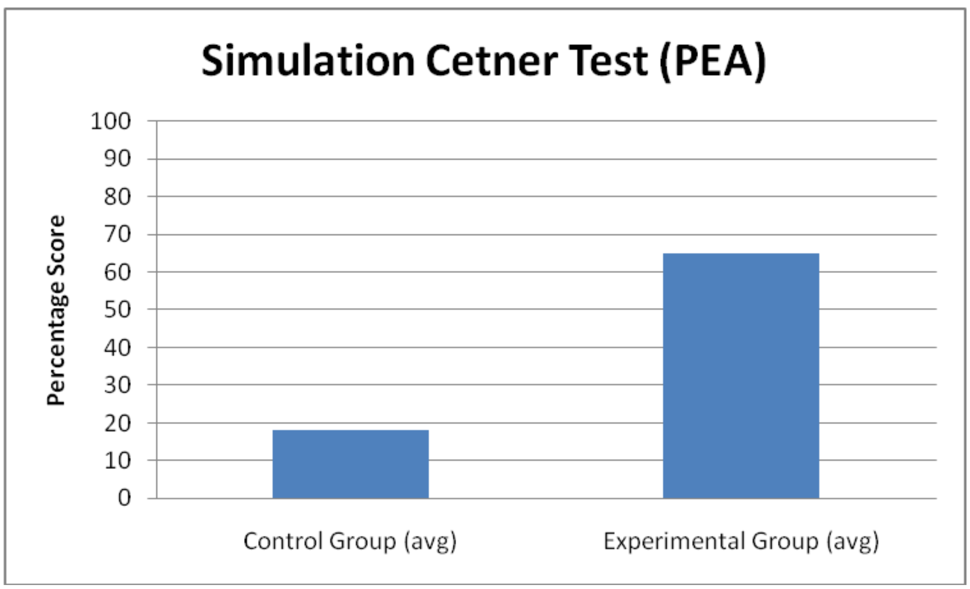

Figure 27. Comparison between control and experimental groups

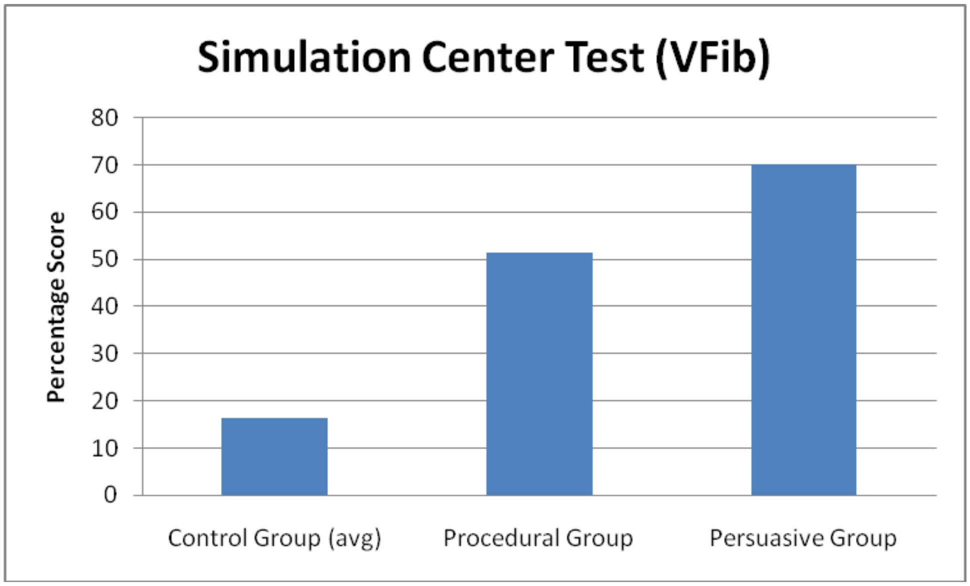

Figure 28. Simulation Center Test - VFib (Transfer test)

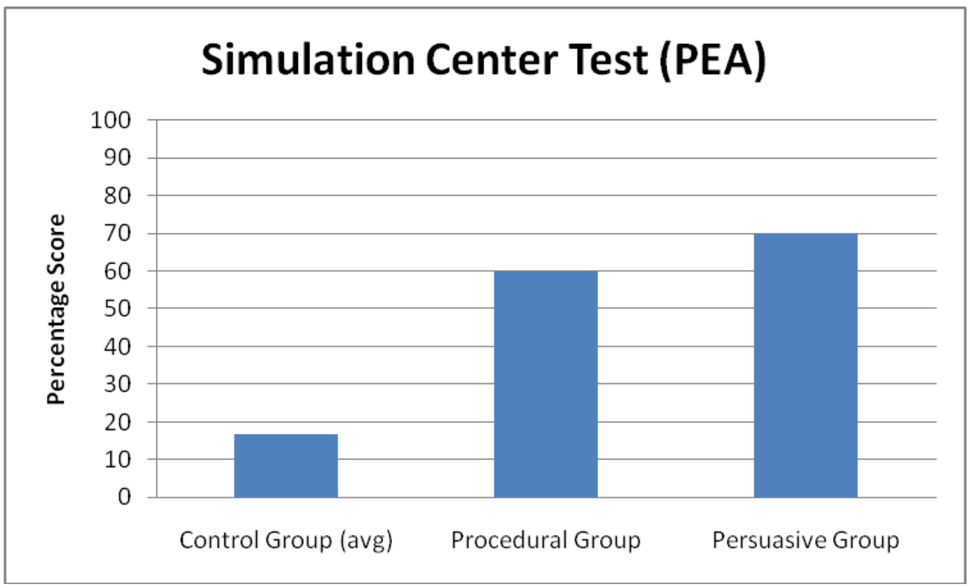

Figure 29. Simulation Center Test - PEA (Transfer test)

The figures 38 and 29 show the performance of the Control Group (avg), procedural group and the persuasive group. These are essentially the results of the same tests at the simulation center; however, they compare the performance of control group, procedural group and persuasive group.

The control groups which did not receive any training in the virtual world, did not perform as well as the other two groups. Procedural group which did not receive any aid from persuasive elements, performed better than the control group but worse than the persuasive group.

Figure 29 shows that control group performed worse than their previous performance. There is a considerable difference (10/100) between the scores of the procedural group and the persuasive group.

This transfer test shows that the participants trained in virtual world could apply those skills in the real world. They performed better than the other control group participants

6.2.4 User Feedback

All of the experimental group participants were asked to fill a feedback questionnaire after the Phase 2 training session. This questionnaire can be found in appendix A. 21 question were laid out in six different categories targeted to obtain feedback about the system in order to evaluate its advantages and limitations. These categories are as follows:

- Ease of use of the simulator
- Haptic – CPR simulation
- Lag experienced in the system
- Aid provided by persuasion during training sessions
- Improvement in CPR skills due to training using this simulator
- Overall rating

Figure 30 shows the average rating given to each category by users.

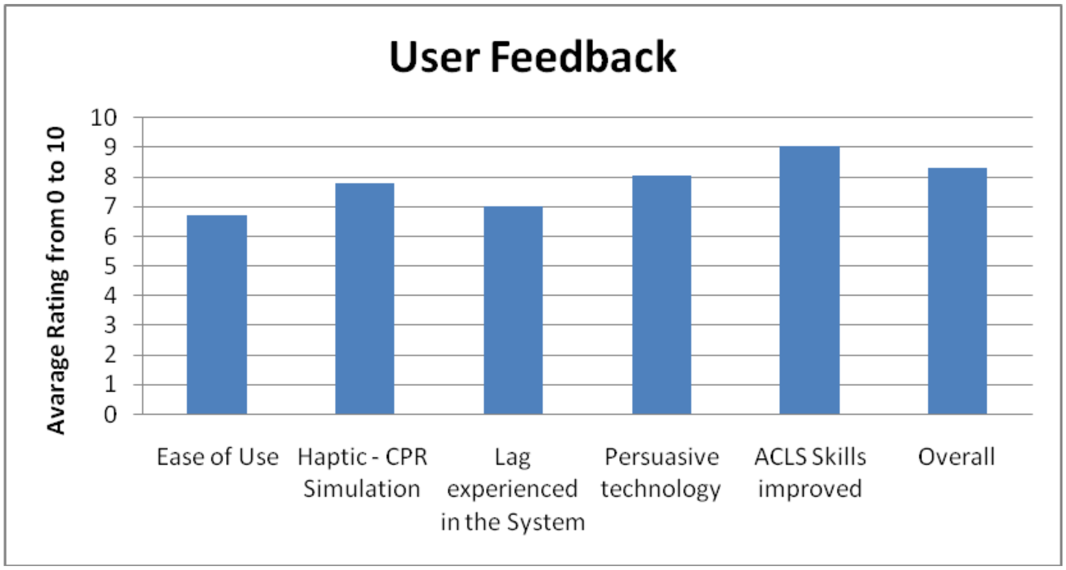

Figure 30. User Feedback

Users liked the overall simulator. They felt that it certainly helped them improve their ACLS skills. All of them liked the integration of haptic device and virtual world. They felt that performing CPR on the haptic device was easy and comfortable. Persuasive group noted that use of persuasive elements aided in the training sessions.

We noticed in the user feedback that there is a room for improvement. The system can be reworked to provide better usability. Users experienced considerable amount of lag in the system. These issues could be focused on in next version of the simulator.

7. CONCLUSION AND FUTURE WORK

This work presents a novel approach for delivering time critical team training. It provides a remotely accessible automated centralized platform that is capable of training and testing teams. It focuses on various aspects of team dynamics such as time criticality, communication, procedural task work and leadership. Historically, individual training has been given preference over team training. This decision is backed by valid limitations such as team is dispersed over several geographical locations, overlapping schedules of team members make them impossible to be present for training sessions at the same time. This particular system overcomes these problems since the system is accessible from disparate locations. Participants can log in remotely at some agreed upon time and participate in several exercises as a team.

This system was successfully implemented and tested. As hypothesized, this system actually trained novices, the procedural aspect of ACLS and was validated in the real world setting. With the use of this system, it is certainly possible to augment real world ACLS training sessions. It showed that the two experimental groups (average score 65/100) performed better than the control groups (average score 16/100). Persuasive elements showed positive signs, however, we would require a larger sample size to reach a definitive conclusion about, whether the persuasive elements help or they don't. This experiment serves as a validation of the system.

In order to provide effective time critical team training, this system successfully combined three areas namely, team training, virtual environments and persuasive technology. Virtual worlds provided a remotely accessible, easy to use and affordable platform for developing simulations for team training exercises. Moreover, the persuasive elements played a key role in facilitating users to better adapt to the simulation.

ACLS professionals from Banner Hospital were consulted during the design and implementation phase of the two ACLS procedures namely, Ventricular Fibrillation and PEA. The ACLS professionals also helped while designing the scoring scheme and performance evaluation scheme for the two procedures. The implementation of these procedures was revised iteratively until it was extremely close to reality. The ACLS professionals were very satisfied with the finished system and were excited to incorporate it in their training curriculum for delivering training of ACLS to professional nurses at Banner simulation centers.

The experimental group was very content after going through ACLS training in the virtual world. The persuasive group was very pleased with the aid provided by persuasive elements. It helped them perform better in the initial training sessions. In the user feedback the system received an average overall rating of 8.25 on a scale of 10. Moreover, the participants voted that they would like to participate in a team training sessions as opposed to individual training in the virtual world as it is more interactive and engaging.

This system certainly overcomes the issues faced by similar studies, however, it has certain limitations, such as, users experienced lag in activities during training sessions. If this issue is not resolved then integrating more number of multisensory devices might impact the training negatively as the training in this case is time-critical and time-lag in activities is unaffordable. The user interface can be reworked to provide better usability. Since it is a computer based simulation, it is not very easy to get 360 degree view from the user's camera perspective. Moreover, this system is incapable of replacing a professional trainer for complex activities such as ACLS. However, it can augment the trainer's abilities to a great extent; as the system is capable of providing training and testing with automated evaluation and feedback.

In the future, this system will be applied to facilitate ACLS training for nurses at Banner hospitals. It would be interesting to see the results when this system will be used and evaluated for professional nurses. It would be interesting to see more focus and variations of persuasive elements. Additional sensors can be integrated to provide training for psychomotor skills. For example, we can integrate accelerometers for teaching chemistry lab experiments. This system can be used to simulate several tactical missions to train military teams across disparate locations. It can used to train high performance teams in various domains such as education, healthcare and emergency services (fire department and EMT).

REFERENCES

Association, American Health. 2010. *Cardiopulmonary Resuscitation* 2005 [cited August 27 2010].

Activewordls-Inc. *Active Worlds* 1995 [cited. Available from www.activeworlds.com.

Aehlert-Mosby, Barbara. 2006. *ACLS Study Guide*.

Boulos, K, R. Ramloll, R. Jones, and S. Toth-Cohen. 2008. Web 3D for public, environmental and occupational health: early examples from second life. *Int J Environ Res Public Health* 5 (4):290-317.

Boulos, M. N., L. Hetherington, and S. Wheeler. 2007. Second Life: an overview of the potential of 3-D virtual worlds in medical and health education. *Health Info Libr J* 24 (4):233-45.

Brown, Barry, and Bell Marek. 2004. CSCW at play: 'there' as a collaborative virtual environment. In *Proceedings of the 2004 ACM conference on Computer supported cooperative work*. Chicago, Illinois, USA: ACM.

Burleson, Winslow, and Roselind Picard. 2004. Affective Learning Companions.

Callaghan, M. J., K. McCusker, J. Lopez Losada, J. G. Harkin, and S. Wilson. 2009. Integrating virtual worlds: virtual learning environments for online education. Paper read at Games Innovations Conference, 2009. ICE-GIC 2009. International IEEE Consumer Electronics Society's, 25-28 Aug. 2009.

Cannon-Bowers, J. A, E. Salas, and S Converse. 2001. *Individual and Group Decision Making, Shared mental models in expert team decision making*: Erlbaum Associates.

Center, Ann Myers Medical. 2010. *Ann Myers Medical Center* 2009 [cited September 1 2010]. Available from http://ammc.wordpress.com/.

Chodos, David, Stroulia Eleni, Boechler Patricia, King Sharla, Kuras Pawel, Carbonaro Michael, and Jong Erik de. 2010. Healthcare education with virtual-world simulations. In *Proceedings of the 2010 ICSE Workshop on Software Engineering in Health Care*. Cape Town, South Africa: ACM.

Conradi, Emily, Sheetal Kavia, David Burden, Alan Rice, Luke Woodham, Chris Beaumont, Maggi Savin-Baden, and Terry Poulton. 2009. Virtual patients in a virtual world: Training paramedic students for practice. *Medical Teacher* 31 (8):713-720.

Ducheneaut, Nicolas, and J. Moore Robert. 2004. The social side of gaming: a study of interaction patterns in a massively multiplayer online game. In *Proceedings of the 2004 ACM conference on Computer supported cooperative work*. Chicago, Illinois, USA: ACM.

Entin, Elliot E., and Daniel Serfaty. 1999. Adaptive Team Coordination. *Human Factors: The Journal of the Human Factors and Ergonomics Society* 41 (2):312-325.

Firpo, Daniel, Kasemvilas Sumonta, Ractham Peter, and Zhang Xuesong. 2009. Generating a sense of community in a graduate educational setting through persuasive technology. In *Proceedings of the 4th International Conference on Persuasive Technology*. Claremont, California: ACM.

Fogg, B. J. 2002. Persuasive technology: using computers to change what we think and do. *Ubiquity* 2002 (December):2.

Hamman, W. R. 2004. The complexity of team training: what we have learned from aviation and its applications to medicine. *Quality and Safety in Health Care* 13 (suppl 1):i72-i79.

Hamman, William R., Jeffrey M. Beaubien, and Beth M. Beaudin-Seiler. 2009. Simulation for the Training of Human Performance and Technical Skills: The Intersection of How We Will Train Health Care Professionals in the Future. *Journal of Graduate Medical Education* 1 (2):245-252.

Johnson C, Vorderstrasse A, Shaw R. 2009. Virtual Worlds in Health Care Higher Education. *Journal of Virtual Worlds Research* 2 (2).

Khanal P, and Kahol K. 2010. Interactive Haptic Virtual Collaborative Training Simulator to Retain CPR Skills: Arizona State University.

MacMillan, J, Entin E. E., and D Serfaty. 2004. *Team Cognition: Understanding the factors that drive Process and Performance*. 1st ed.

Pedersen, Paul. 1995. Simulations: A Safe Place to Take Risks in Discussing Cultural Differences. *Simulation & Gaming* 26 (2):201-206.

Rodrigo de, Oliveira, and Oliver Nuria. 2008. TripleBeat: enhancing exercise performance with persuasion. In *Proceedings of the 10th international conference on Human computer interaction with mobile devices and services*. Amsterdam, The Netherlands: ACM.

Schwid, Howard A., G. Alec Rooke, Brian K. Ross, and Murali Sivarajan. 1999. Use of a computerized advanced cardiac life support simulator improves retention of advanced cardiac life support guidelines better than a textbook review. *Critical Care Medicine* 27 (4):821-824.

Seitz, Aaron R., Robyn Kim, and Ladan Shams. 2006. Sound Facilitates Visual Learning. *Current biology : CB* 16 (14):1422-1427.

Shams, Ladan, and Aaron R. Seitz. 2008. Benefits of multisensory learning. *Trends in Cognitive Sciences* 12 (11):411-417.

Services, Exploratorium Exhibit. 2010. *Exploratorium Exhibit Services: HIV Roulette* 2006 [cited September 25 2010]. Available from http://exs.exploratorium.edu/exhibits/hiv-roulette/.

Toups, Zachary, Kerne Andruid, Hamilton William, and Blevins Alan. 2009. Emergent team coordination: from fire emergency response practice to a non-mimetic simulation game. In *Proceedings of the ACM 2009 international conference on Supporting group work*. Sanibel Island, Florida, USA: ACM.

Tsiatsos, T, K Andreas, and P Andreas. 2009. Collaborative Educational Virtual Environments Evaluation. *Workshop on Intelligent and Innovative Support for Collaborative Learning Activities*.

Tsiatsos, Thrasyvoulos, Konstantinidis Andreas, Ioannidis Lazaros, and Tseloudi Crysanthi. 2009. Implementing Collaborative e-Learning Techniques in Collaborative Virtual Environments: The Case of Second Life. In *Proceedings of the 2009 Fourth Balkan Conference in Informatics*: IEEE Computer Society.

VNEC. 2010. *VNEC* 2006 [cited September 27 2010]. Available from http://www.vnec.co.uk.

Wayne, Diane B., John Butter, Viva J. Siddall, Monica J. Fudala, Leonard D. Wade, Joe Feinglass, and William C. McGaghie. 2006. Mastery Learning of Advanced Cardiac Life Support Skills by Internal Medicine Residents Using Simulation Technology and Deliberate Practice. *Journal of General Internal Medicine* 21 (3):251-256.

Wiecha, J., R. Heyden, E. Sternthal, and M. Merialdi. 2010. Learning in a virtual world: experience with using second life for medical education. *J Med Internet Res* 12 (1):e1.